ELSEVIER

Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Engineering 29 (2012) 2809 – 2813

Procedia Engineering

www.elsevier.com/locate/procedia

2012 International Workshop on Information and Electronics Engineering (IWIEE)

A Real-Time, Wireless Pressure Monitoring System for Bucking Bulls

Siyu Li[a,b], Ning Wang[b], Hongju Gao [a*], Shujie Pang[c]

[a]*Key Laboratory of Modern Precision Agriculture System Integration Research, Ministry of Education, College of Information and Electrical Engineering, China Agricultural University, Beijing, 100083*
[b]*Department of Biosystems and Agricultural Engineering, Oklahoma State University, 111 Ag Hall, Stillwater,USA*
[c] *Chinnese Academy of Agricultural Mechanization Sciences*

Abstract

To evaluate the animal welfare, many ranchers would like to know the pressure on the animals due to the holsters and ropes. In this paper, a wireless real-time pressure monitoring system was designed based on wireless sensor network. The system consists of several pressure sensor nodes and a sink to coordinate the whole network, collect data from pressure sensor nodes and send the data to PC. An ultra-thin pressure sensor was integrated in the smart mote platform to form the pressure sensor node. TinyOS, an open-source operating system and nesC language, an extension to C were applied for programming. In the lab test, the result of sensor calibration shows it has a good linearity and the packet delivery rate test verify that the system could operate stably and reliably in a better acceptable link quality. For better presenting to users, an information monitoring interface was used based on MATLAB as a simple demonstration of the whole system.

Keywords: animal welfare; wireless pressure sensor; real-time monitoring system; TinyOS

1. Introduction

Bucking bull riding refers to rodeo sports that involve a rider getting on a large bull and attempting to stay mounted while the animal attempts to buck off the rider. In the American tradition the rider must stay

* Corresponding author. Tel.: 010-62738830, 13699135738.
E-mail address: hjgao@cau.edu.cn.

doi:10.1016/j.proeng.2012.01.395

atop the bucking bull for eight seconds. The rider tightly fastens one hand to the bull with a long braided rope. It is a risky sport and has been called "the most dangerous eight seconds in sports"[1]. There is heated debate between animal rights organizations and bull riding enthusiasts over many aspects of the sport. One source of controversy is the flank strap, which is placed around a bull's flank, just in front of the hind legs, to encourage bucking. To evaluate the animal welfare, farmers and ranchers would like to know the pressure on the animals due to the holsters and ropes. They have been working with animal scientists, agricultural engineers and animal well-being experts to develop and support best management practices focused on proper care, handling, and facilities of animals.

Recent advances in sensor and wireless radio frequency (RF) technologies and their convergence with the Internet offer vast opportunities for development and application of sensor systems for agriculture [2]. The emerging technologies of wireless sensor network (WSN) provide new economic opportunities for agriculture through their application to remote, real-time monitoring and control of important aspects of high quality food production and processing systems [2]. Nagl et al. (2003) [3] designed a wearable remote health monitoring system for cattle that hosts a suite of sensors and communicates wirelessly with a base station via Bluetooth telemetry. Zhang et al. [4] designed ZebraNet system which was composed of mobile wireless sensor nodes to track animal migrations. ZebraNet aims at accurately monitoring and analyzing data collected from the nodes built into the zebra's collar. Sousa Silva et al. [5] presents a low-cost wireless communication protocol to monitor physiological responses of livestock through monitoring the bovine brain electrical activity. Bishop-Hurley [6] implements an automated cattle control system to manage livestock movement. A collar-halter device was designed to carry the electronics, batteries and equipment providing the stimuli to modify the behaviour of the cattle successfully. In this paper, a real-time, wireless pressure monitoring system was designed to acquire the pressure information impacted by a rope used on bucking bulls. The specific objective includes increasing the sampling speed to collect more data in limited time and stably and reliably transmitting the data to monitoring interface.

2. Wireless Pressure Sensor System

Wireless pressure sensor system consists of a sink and several wireless pressure sensor nodes. In the bullfight, the bullring is a limited-area place and the data transmitted from wireless pressure sensor nodes to sink can be within one-hop transmission range, typically 70m. Besides, the sampling speed of each pressure node is very fast, it is more feasible to use less routing message to save more bandwidth. Hence, a simplest network topology, star network, is utilized in this specific application. The sink, which acts as a coordination point to transmit data, provides a common connection point for all wireless pressure sensor nodes, illustrated in Fig.1. For each practice, one node with more sensors needs to be installed on the rope because of one bull rider in each rodeo. Hence, the system mainly becomes a point-to-point communication, which has more practical value.

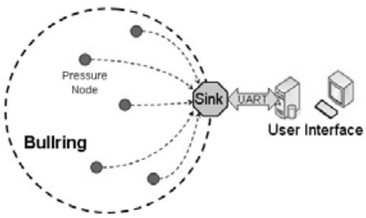


Fig. 1 Architecture of Wireless Pressure Monitoring System

3. Hardware Design

The wireless pressure sensor node consists of four pressure sensors, a power supply, a signal conditioning circuit and a mote, shown in Fig. 2(a). Mica2Dot Mote (Crossbow Technology Inc., San Jose, CA, USA) was used as a transceiver, Fig. 2(b). This mote is the smallest mote platform in Crossbow family, with a diameter of 25mm, which is designed specifically for deeply embedded wireless sensor network systems and for applications where physical size is important. The following features make the Mica2Dot better suited for this specific application. It utilizes a powerful ATMega128L micro-controller and the Chipcon CC1000 FSK-modulated radio working in 868/916MHz channel transceiver with extended range; supports TinyOS (TOS) distributed software operating system with improved networking stack, improved debugging features and wireless remote reprogramming; includes 128KB program Flash memory, 512KB measurement (serial) Flash and 4KB configuration EEPROM; features 18 solderless expansion pins for connecting 6 Analog Inputs, Digital I/O and a serial communication interface, which make it easy to connect to a wide variety of external peripherals [7].

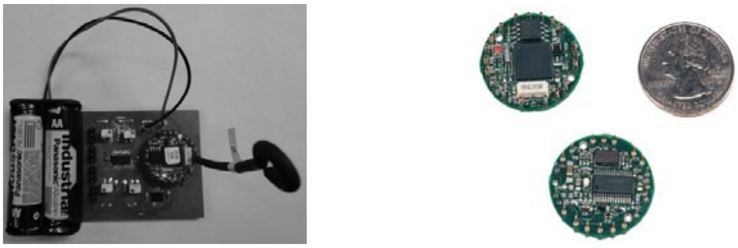


Fig. 2 (a) wireless pressure sensor node (b) Mica2Dot

The four pressure sensors are standard FlexiForce sensors produced from Tekscan Inc. The FlexiForce sensor is ultra-thin and flexible printed circuits, shown in Fig. 3(a), which can be easily integrated into force measurement applications, such as detection and measurement of a relative change in force or applied load and the rate of change in force. The FlexiForce sensor is constructed of two layers of substrate (polyester) film, a conductive material (silver) and a layer of pressure-sensitive ink [8], shown in Fig.3(b). It acts as a force sensing resistor in an electrical circuit. When the FlexiForce sensor is unloaded, its resistance is very high. While when a force is applied to the sensor, this resistance decreases. The result of three sets of test about resistance variance with the applied force is shown in Fig. 3(c). The Flexiforce sensor could be easily integrated in an operational amplification circuit to make sure a standard analog output.

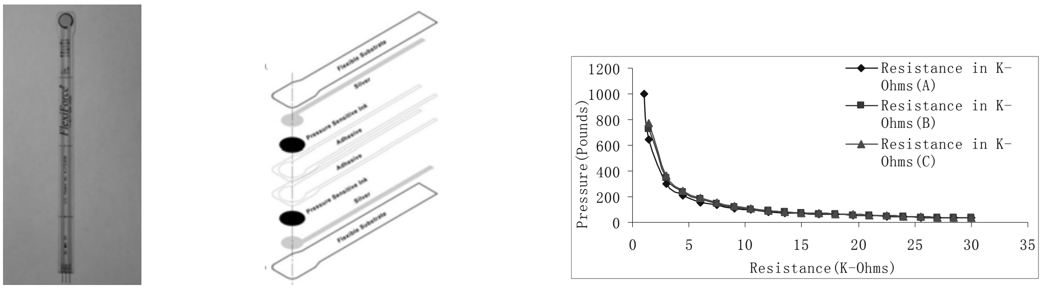
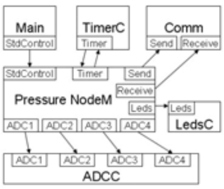


Fig. 3(a) FlexiForce Sensor (b) Construction of FlexiForce [8] (c) Resistance vs. Force

4. Software Design

Software on all nodes is based on TinyOS system, an open-source operating system designed for wireless embedded sensor networks. It features a component-based and event-driven architecture, which enables rapid innovation and implementation while minimizing code size as required by the severe memory constraints inherent in sensor network [9]. All programs are written in nesC (network embedded systems C), an extension to C designed to embody the structuring concepts and execution model of TinyOS. Programs are built out of components, which are wired to form whole programs. There are two types of components in nesC: modules and configurations. Modules provide application code, implementing one or more interface. Configurations are used to assemble other components together, connecting interfaces used by components to interfaces provided by others. The program structure of the pressure sensor nodes is shown in Fig. 4(a). The application program consists of 6 components: Main, Pressure NodeM, TimerC, Comm, LedsC and ADCC. Main component is the top-level configuration of each TinyOS application program. Pressure NodeM component is the application component designed for different specific application, TimerC component is used for control the node status and the sampling interval, Comm component is used for data sending and receiving. ADCC component is used for data collection, and LedsC component is used for program debugging. All components are wired by interfaces, such as StdControl, Timer, Send, and Receive, etc. When the pressure sensor node is powered up, the program begins and initializes all components. When Timer is fired, the Pressure NodeM calls the ADC components to collect the data and send the data by radio through Comm component. To demonstrate the wireless pressure monitoring system to ranchers and animal scientists, a simple information monitoring interface is used based on MATLAB, shown in Fig. 4(b). The upper part is to real-time presentation of the four sensors and the lower part is to display the history information of each sensor.



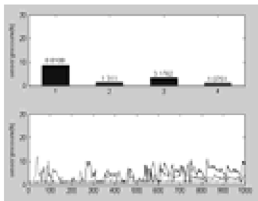


Fig. 4(a) Program Structure of Pressure Nodes (b) Information Monitoring Interface

5. Experiment results and discussion

Fig. 5(a) shows the installation of sensors on the rope. Before application, all sensors need to be calibrated. Calibration is the method by which the sensor's electrical output is related to an actual engineering unit, such as Pound or Newton. To calibrate, a number of known forces that approximate the load range are repeatedly applied to the sensor, and the sensor resistance outputs equated to these forces are measured in testing. The pressure versus analog output of the sensor after amplifier and filter circuit is illustrated in Fig. 5(a). It is clearly that the sensor has a good linearity and repeatability. To test the stability and reliability of the pressure monitoring system, packet delivery rate is tested for 10 rounds at 10 different sampling and sending intervals, from once/seconds to 10 times/seconds. In each round, 100 packets are collected and sent by the pressure sensor node at each sampling interval. The result of packet delivery rate test is shown in Fig. 5(b). It shows that the performance of the system is better with the less sampling and sending rate and the packet delivery rate is 93.2% in average. With 10 times/second sampling interval, the performance is worst and the packet delivery rate is about 88.8% in average. However, this result is also acceptable for the application.

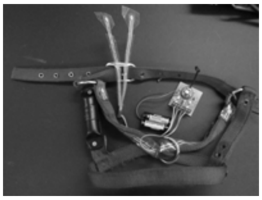
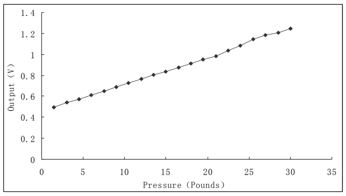
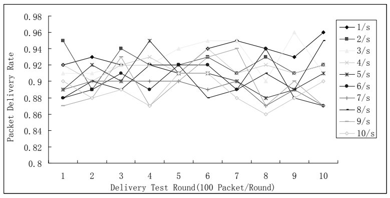


Fig. 5(a) Installation of sensors



(b) Pressure vs. Analog output



(c) Packet Delivery Rate Test

6. Conclusion

In this paper, to evaluate the animal welfare, a wireless real-time pressure monitoring system was designed based on wireless sensor network. The system consists of several pressure sensor nodes and a sink to coordinate the whole network, collect data from pressure sensor nodes and send the data to PC. An ultra-thin pressure sensor was integrated in the smart mote platform to form the pressure sensor node. TinyOS, an open-source operating system and nesC language, an extension to C were applied for programming. In the lab test, the result of sensor calibration shows it has a good linearity and the packet delivery rate test verify that the system could operate stably and reliably in a better acceptable link quality. For better presenting to users, an information monitoring interface was used based on MATLAB as a simple demonstration of the whole system. As a specific application, this paper gives a simple solution to ranchers and animal scientists to know the pressure on the animals due to the holsters and ropes and then to evaluate the animal welfare based on these collected information.

Acknowledgments

The author would like to acknowledge the support from National High Technology Research and Development Program (863):2011AA100704 and the support from Prof. Wang and lab staffs in Sensor Lab of Department of Biosystems and Agricultural Engineering, Oklahoma State University, USA.

References

[1] Zoltan Istvan. Facing the Bull: The Most Dangerous Eight Seconds in Sports. National Geographic Channel. Feb.25, 2004. http://channel.nationalgeographic.com/channel/

[2] F. J. Pierce, T. V. Elliott. Regional and on-farm wireless sensor networks for agricultural systems in Eastern Washington[J], Computers and Electronics In Agriculture, April 2008, Vol.61, Iss. 1, pp. 32-43.

[3]Nagl. L., Schmitz. R., Warren. S., et al. Wearable sensor system for wireless state-of-health determination in cattle. Proceedings of the 25^{th} IEEE EMBS Conference, Cancun, Mexico, Sep. 17-21, 2003.

[4]P. Zhang, C. M. Sadler, S. A. Lyon, M. Martonosi. Hardware design experiences in ZebraNet. Proceeding of the SenSys'04, Baltimore, MD, 2004.

[5]Ana Carolina de Sousa Silva, Aldo Ivan C'espede Arce, S'ergio Soute, et al. A wireless floating base sensor network for physiological responses of livestock. Computers and Electronics in Agriculture. 2005(49), pp 246-255.

[6]G. J. Bishop-Hurley, D. L. Swain, D. M. Anderson, etc. Virtual fencing applications: Implementing and testing an automated cattle control system. Computers and Electronics in Agriculture. 2007(56), pp 14-22.

[7] http://www.xbow.com/

[8] http://www.tekscan.com/

[9] "TinyOS tutorial", http://www.tinyos.net/